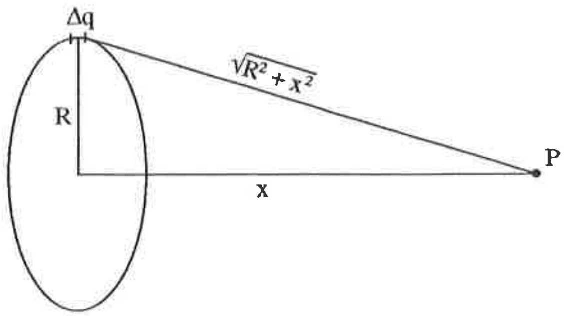
51.



Potential at P due to $\Delta q = \dfrac{\Delta q}{4\pi\varepsilon_0\sqrt{R^2+x^2}}$ since potential is a scalar. The potential due to the entire ring is simply $\dfrac{\Sigma\Delta q}{4\pi\varepsilon_0\sqrt{R^2+x^2}}$.

$$V = \frac{Q}{4\pi\varepsilon_0\sqrt{R^2+x^2}}.$$

Chapter 18

1. $Q = It = (4.5\ \text{A})(7\ \text{h})(3600\ \text{s/h}) = \underline{1.1 \times 10^5\ \text{C}}$.

2. $N = Q/e = \dfrac{(1\ \text{C/s})(1\ \text{s})}{1.6 \times 10^{-19}\ \text{C}} = \underline{6.25 \times 10^{18}}$

3. $I = \dfrac{Q}{t} = \dfrac{(1000)(1.6 \times 10^{-19}\ \text{C})}{4 \times 10^{-6}\ \text{s}} = \underline{4 \times 10^{-11}\ \text{A}}$

4. $V = IR = (0.15\ \text{A})(3000\ \Omega) = \underline{450\ \text{V}}$

5. $R = \dfrac{V}{I} = \dfrac{120\ \text{V}}{3.5\ \text{A}} = \underline{34.3\ \Omega} = \underline{34\ \Omega}$

6. (a) Since $V = IR$, if R stays constant, current will drop 10% as well, to $\underline{2.70\ \text{A}}$.

(b) $R = \dfrac{120\ \text{V}}{3\ \text{A}} \times 0.9 = 36\ \Omega$

$I = \dfrac{V}{R} = \dfrac{120\ \text{V}}{36\ \Omega} = \underline{3.33\ \text{A}}$

7. Number $= \dfrac{Q}{e} = \dfrac{It}{e} = \dfrac{Vt}{Re} = \dfrac{(1.5\ V)(60\ \text{s})}{(1.2\ \Omega)(1.6 \times 10^{-19}\ \text{C})} = \underline{4.69 \times 10^{20}}$

8. $V = IR = (1500\ \text{A})(1.8 \times 10^{-5}\ \Omega/\text{m})(0.03\ \text{m}) = \underline{8.1 \times 10^{-4}\ \text{V}}$

9. $I = Q/t = e\rho vA$. Hence $v = (1\ \text{A})/(1.6 \times 10^{-19}\ \text{C})/(10^{29}/\text{m}^3)/(\pi \times 10^{-6}\ \text{m}^2) = \underline{1.99 \times 10^{-5}\ \text{m/s}}$.
We have used vA as the volume swept out in a second. We have also worked out the averag velocity not speed.

10. $R = \dfrac{\rho \ell}{A} = \dfrac{(1.68 \times 10^{-8}\ \Omega\cdot\text{m})(3\ \text{m})}{\pi(0.75 \times 10^{-3})^2} = 2.85 \times 10^{-2}\ \Omega$

11. $A = \rho L/R = \pi r^2$

$d = 2r = 2(\rho L/\pi R)^{\frac{1}{2}}$

$= 2[(5.6 \times 10^{-8}\ \Omega\cdot\text{m})(0.30\ \text{m})/[\pi(0.20\ \Omega)]^{\frac{1}{2}}$
$d = 3.27 \times 10^{-4}\ \text{m} = \underline{0.327\ \text{mm}}$

12. $R_2 = R_1\left[\dfrac{\ell_2}{\ell_1}\right]\left[\dfrac{d_1^2}{d_2^2}\right] = (2.8\ \Omega)\left[\dfrac{30\ \text{m}}{25\ \text{m}}\right]\dfrac{(1.8\ \text{mm})^2}{(3\ \text{mm})^2} = \underline{1.21\ \Omega}$

13. Yes. $R_2 = R_1(\rho_2/\rho_1)(d_1^2/d_2^2)$.

If R_2 and R_1 are the same, $d_2 = d_1(\rho_2/\rho_1)^{\frac{1}{2}} = (2.00\ \text{mm})(5.6/1.68)^{\frac{1}{2}} = \underline{3.65\ \text{mm}}$.

14. $\rho_T = \rho_0(1 + \alpha\Delta T)$
$1.25 = (1 + 0.0068(\text{C}^{\text{o}-1})\Delta T)$

$\Delta T = \dfrac{0.25}{0.0068\ \text{C}^{-1}} = \underline{36.8°\text{C}}$.

$1.68 \times 10^{-8} = 5.6 \times 10^{-8}[1 + (0.0045)\Delta T]$
$\Delta T = -156\ \text{C}°$
$T = 20°\text{C} - 156\text{C}° = \underline{-136°\text{C}}$

16. $R_{\text{HOT}} = R_{\text{COLD}}[1 + \alpha\Delta T]$. Hence $\Delta T = [(140\ \Omega)/(12\ \Omega) - 1]/(0.0060/°\text{C}) = \underline{1778°\ \text{C}} = 1.8 \times 10^3\text{C}°$.

17. (a) $R = \dfrac{(3.0 \times 10^{-5}\ \Omega\cdot\text{m})(0.01\ \text{m})}{(0.02\ \text{m})(0.03\ \text{m})} = 5.0 \times 10^{-4}\ \Omega$

(b) $R = \dfrac{(3.0 \times 10^{-5}\ \Omega\cdot\text{m})(0.02\ \text{m})}{(0.01\ \text{m})(0.03\ \text{m})} = 2.0 \times 10^{-3}\ \Omega$

(c) $R = \dfrac{(3.0 \times 10^{-5}\ \Omega\cdot\text{m})(0.03\ \text{m})}{(0.01\ \text{m})(0.02\ \text{m})} = 4.5 \times 10^{-3}\ \Omega$

18. Assume the wires are welded end to end.

$$R = R_1 + R_2, \qquad R_1 = \frac{(1.68 \times 10^{-8}\ \Omega\cdot\text{m})(6\text{ m})}{\pi(1 \times 10^{-3}\ \text{m})^2} = 0.0321\ \Omega$$

$$R_2 = \frac{(2.65 \times 10^{-8}\ \Omega\cdot\text{m})(6\text{ m})}{\pi(1 \times 10^{-3}\ \text{m})^2} = 0.0506\ \Omega$$

$V = I(R_1 + R_2) = (8\text{ A})(0.0506\ \Omega + 0.0321\ \Omega) = \underline{0.66\text{ V}}$.

19. $R = R_1 + R_2 = R_{10}(1 - 0.0005\Delta T) + R_{20}(1 + 0.0004\Delta T)$
At zero degree, $R_{10} + R_{20} = 2.8 \times 10^3\ \Omega$.
If R is not to change, $-0.0005R_{10} + 0.0004R_{20} = 0$
$R_{20} = \underline{1.56 \times 10^3\ \Omega}$, $R_{10} = \underline{1.24 \times 10^3\ \Omega}$

20. $R = V^2/P = (240\ V)^2/(3 \times 10^3\ W) = \underline{19.2\ \Omega}$.

21. $I = \dfrac{P}{V} = \dfrac{40\ W}{12\ V} = \underline{3.33\text{ A}}$.

22. $P = VI = (9\ V)(300 \times 10^{-3}\text{ A}) = \underline{2.7\text{ W}}$.

23. $V = (RP)^{\frac{1}{2}} = \left[(300\ \Omega)\left(\dfrac{1}{4}\ W\right)\right]^{\frac{1}{2}} = 8.66\text{ V}$.

24. $P = IV = (150\text{ A})(12\text{ V}) = \underline{1800\text{ W}}$.

25. A KWh is $(10^3\text{ W})(3600\text{ s}) = 3.6 \times 10^6\text{ J}$

$$\text{KWh used} = \frac{(1300\text{ J/s})(45\text{ min})(60\text{ s/min})}{3.6 \times 10^6\text{ J/KWh}} = \underline{0.975\text{ KWh}}$$

26. Cost = (Energy consumed)(cost/KWh)
= (25 J/s)(3600 s/h)(24 h/d)(0.080 \$/kWh)/(3.6×10^6 J/kWh)
= 0.048 \$d or $\underline{\$17.52\text{ per year}}$.

27. Energy stored = (40 A)(12 V)(3600 s) = $\underline{1.73 \times 10^6\text{ J}}$

28. Each bulb draws $\frac{100 \text{ W}}{120 \text{ V}} = 0.833 \text{ A}$

$$n = \frac{20 \text{ A}}{0.833 \text{ A}} = \underline{24 \text{ bulbs}}.$$

29. Efficiency = (100%)(0.5 × 740 W)/(4.4 A)/(120 V) = $\underline{70.1\%}$.

30. $I = \frac{P}{V} = \frac{440 \times 10^3 \text{ W}}{12000 \text{ V}} = 36.67 \text{ A}$

Power consumed in lines is $I^2R = (36.67 \text{ A})^2(3\ \Omega) = 4.033 \text{ kW}$.

At 40,000 V, $I = \frac{440 \times 10^3 \text{ W}}{40,000 \text{ V}} = 11 \text{ A}$

Power consumed = $(11 \text{ A})^2(3\ \Omega) = 363 \text{ W}$
Power saved = $\underline{3.67 \text{ kW}}$.

31. $\Delta T = \left[\frac{Q}{s}\right] / \left[\frac{m}{s}\right] / c$

Hence mass per sec is $\frac{(240 \text{ V})(7.6 \text{ A})}{(4180 \text{ J/kg}^\circ\text{C})(6^\circ\text{C})} = 0.0727 \text{ kg/s}$ or $\underline{262 \text{ kg/h}}$

32. $I = \left[\frac{Q}{t}\right] / V = \frac{mc\Delta T}{tV} = \frac{(90^\circ\text{C})(200 \times 10^{-3} \text{ kg})(4180 \text{ J/kg}\cdot{}^\circ\text{C})}{(6 \text{ min})(60 \text{ s/min})(12 \text{ V})} = 17.4 \text{ A}$

33. 240 V refers to rms value.

Peak voltage = $\sqrt{2}(240 \text{ V}) = 339.4 \text{ V} = \underline{339 \text{ V}}$

$I_{peak} = \frac{339.4 \text{ V}}{3.2 \text{ k}\Omega} = \underline{0.106 \text{ A}}$.

34. $I = \frac{V}{R}$, peak current is $\frac{180 \text{ V}}{220\ \Omega} = \underline{0.818 \text{ A}}$.

rms current is $\frac{(0.818 \text{ A})}{\sqrt{2}} = \underline{0.578 \text{ A}}$.

35. $R = V^2/P = (120 \text{ V})^2/60 \text{ W} = 240\ \Omega$

36. $V_{rms} = \dfrac{1000\ \text{W}}{\dfrac{1}{\sqrt{2}}(3\ \text{A})} = \underline{470\ \text{V}}$ or $\underline{4.7 \times 10^2\ \text{V}}$.

37. $I = \dfrac{\sqrt{2}(75\ \text{W})}{120\ \text{V}} = \underline{0.884\ \text{A}}$.

38. $P_{peak} = I_{peak}V_{peak} = (\sqrt{2})(\sqrt{2})V_0I_0 = 2P_{rms} = \underline{200\ \text{W}}$.

39. $P = \dfrac{V^2}{R} = \dfrac{(240\ \text{V})^2}{15\ \Omega} = 3.84\ \text{kW}$.

Maximum power is twice of this, i.e. = $\underline{7.68\ \text{kW}}$.
Minimim power is $\underline{\text{zero}}$.

40. $E = V/d = (70 \times 10^{-3}\ \text{V})/(10^{-8}\ \text{m}) = \underline{7 \times 10^6\ \text{V/m}}$.

41. $v = (7.2 \times 10^{-2}\ \text{m} - 3.4 \times 10^{-2}\ \text{m})/(0.0063\ \text{s} - 0.0052\ \text{s}) = \underline{34.5\ \text{m/s}}$.
The nerve response time must be eliminated.

42. $E = CV^2/2 = (10^{-8}\ \text{F})(100 \times 10^{-3}\ \text{V})^2/2 = \underline{5 \times 10^{-11}\ \text{J}}$.
$P = E/t = (5 \times 10^{-11}\ \text{J})(10^4)(100\ \text{pulses/s}) = \underline{5 \times 10^{-5}\ \text{W}}$.

43. Current per m² is $(3 \times 10^{-7}\ \text{mol/m2}\cdot\text{s})(6.02 \times 10^{23}\ \text{ions/mol})(1.6 \times 10^{-19}\ \text{C/ion}) = 2.89 \times 10^{-2}\ \text{A/m}^2$
$P = IV = (2.89 \times 10^{-2}\ \text{A/m}^2)(0.1\ \text{m})(2\ \pi)(10^{-5}\ \text{m})(30 \times 10^{-3}\ \text{V}) = \underline{5.45 \times 10^{-9}\ \text{W}}$.

44. 1 ampere – hour = $(1\ \text{C/s})(1\ \text{h})(3600\ \text{s/h}) = \underline{3600\ \text{C}}$.

45. Assume $V = 120\ \text{V}$.
$I = (0.5\ \text{hp})(746\ \text{W/hp})/(120\ \text{V}) = \underline{3.1\ \text{A}}$.

46. $I = P/V = (92\ \text{W})/(12\ \text{V}) = 7.67\ \text{A}$
Time = $(45\ \text{A}\cdot\text{h})/(7.67\ \text{A}) = \underline{5.87\ \text{h}}$.
A·h refers to the total charge on the battery.

47. $P = V^2/R$, $R = V^2/P = (120\ \text{V})^2/(1800\ \text{W}) = 8\ \Omega$
$R = \rho L/[\pi(d/2)^2]$

$d = [4\rho L/\pi R]^{\frac{1}{2}} = \{4(9.71 \times 10^{-8}\ \Omega\cdot\text{m})(7.0\ \text{m})/[\pi(8\ \Omega)]\}^{\frac{1}{2}} = \underline{0.329\ \text{mm}}$.

48. $V = IR$, $R = V/I$, $G = 1/R = I/V = (0.70\ \text{A})/(3.0\ \text{V}) = \underline{0.233\ \text{siemens}}$.

49. (a) $P = (1500\ \text{W})(2.5\ \text{h}) + 6(100\ \text{W})(6\ \text{h}) + (3300\ \text{W})(1.2\ \text{h}) + 1600\ \text{W}\cdot\text{h} = 12.91\ \text{kWh/d}$
Cost $= (12.91\ \text{kW}\cdot\text{h/d})(30\ \text{d})(\$0.090/\text{kW}\cdot\text{h}) = \$34.86$

(b) Total $P = (365\ \text{d/y})(12.91\ \text{kW}\cdot\text{h/d}) = 4.71 \times 103\ \text{kW}\cdot\text{h/y} = 12.91\ \text{kWh/d}$
Power plant puts out
$(0.35)(7000\ \text{kcal/kg})(4180\ \text{J/kcal}) = 1.02 \times 10^7\ \text{J/kg}$
$M_{coal} = (4.71 \times 10^3\ \text{kW}\cdot\text{h})(3.6 \times 10^6\ \text{J/kW}\cdot\text{h})/(1.02 \times 10^7\ \text{J/kg}) = 1660\ \text{kg/y}$

50. $R_1 = \rho L_1/A_1$

$L_2 = \frac{1}{2}L_1$, $A_2 = 2A_1$
$R_2 = \rho(L_1/2)/(2A_1) = (\rho L_1/A_1)/4 = \underline{R_1/4}$

$R = V^2/P = (117\ \text{V})^2/(1200\ \text{W}) = 11.4\ \Omega$.
New power $= (105\ \text{V})^2/(11.4\ \Omega) = 966\ \text{W}$ or a $\underline{19.5\%\ \text{drop}}$.
Resistance would be less because temperature would drop, so power would not drop as much as we have calculated.

52. $R = P/I^2 = (1.8\ \text{W})/(40\ \text{A})^2 = 0.001125\ \Omega$.

But $d = (4\ \rho\ell/\pi R)^{\frac{1}{2}} = [(4)(1.68 \times 10^{-8}\ \Omega\cdot\text{m})(1\ \text{m})/\pi/0.001125\ \Omega]^{\frac{1}{2}}$.
$d = \underline{4.36\ \text{mm}}$.

53. (a) $\omega = 180$ rad/s or $\underline{28.6\ \text{Hz}}$.

(b) $\frac{2}{\sqrt{2}}$ A $= \underline{1.41\ \text{A}}$.

(c) $V_0 = (2\ \text{A})(50\ \Omega) = 100\ \text{V}$
$\underline{V = 100 \sin 180\ t}$, V in volts, t in sec

54. $R_1 = \rho L_1/A_1$
$\text{Vol} = L_1A_1 = L_2A_2$
$L_2 = 2L_1$, so $A_2 = A_1/2$
$R_2 = \rho L_2/A_2 = \rho(2L_1)/(A_1/2) = 4\ \rho L_1/A_1 = 4R_1 = 4(1.00\ \Omega) = \underline{4.00\ \Omega}$.

55. $R_1 = \rho L_1/\pi r_1^2$
$L_1 = 2L_2$
$r_1 = 2r_2$
$R_1 = \rho(2L_2)/\pi(2r_2)^2 = (\rho L_2/\pi r_2^2)/2 = R_2/2$
$P_2 = V^2/R_2$
$P_1 = V^2/R_1 = 2V^2/R_2 = 2P_2$
$P_1/P_2 = \underline{2}$

56. Mass of air/time $= \left[\dfrac{273}{299}\right](1.29\ \text{kg/m}^3)(45\ \text{m}^3)/(1800\ \text{s}) = 3.00 \times 10^{-2}\ \text{kg/s}$

$Q/t = mc\Delta T/t = (300 \times 10^{-2}\ \text{kg/s})(0.17\ \text{kcal/kg}\cdot\text{C}^\circ)(15\ \text{C}^\circ) + (550\ \text{kcal})/(3600\ \text{s})$
$= (0.229\ \text{kcal/s} \times (4180\ \text{J/kcal}) = 959\ \text{J/s}$
At 100% efficiency heater must put out $\underline{959\ \text{W}}$.

57. (a) $30\ \text{km/h} = 8.33\ \text{m/s}$
$P = Fv = (220\ \text{N})(8.33\ \text{m/s}) = 1833\ \text{W}/(746\ \text{W/hp}) = \underline{2.46\ \text{hp}}$.

(b) Energy in battery $= (10)(70\ \text{A}\cdot\text{h})(12\ \text{V}) = 8400\ \text{W}\cdot\text{h}$
Time $= (8400\ \text{W}\cdot\text{h})/(1833\ \text{W}) = 4.58\ \text{h}$
Distance $= (30\ \text{km/h})(4.58\ \text{h}) = \underline{137\ \text{km}}$

58. $R = \rho L/A, \quad m = DLA, \quad A = \pi(d/2)^2$
$A = M/DL$
$R = \rho L/(M/DL) = \rho L^2D/\text{m}$

$L = (RM/\rho D)^{\frac{1}{2}} = \{(15.0\ \Omega)(0.0142\ \text{kg})/[(1.68 \times 10^{-8}\ \Omega\cdot\text{m})(8.9 \times 10^3\ \text{kg/m}^3)]\}^{\frac{1}{2}}$
$L = \underline{37.8\ \text{m}}$
$A = M/DL = (0.0142\ \text{kg})/[(8.9 \times 10^3\ \text{kg/m}^3)(30.1\ \text{m})] = 5.31 \times 10^{-8}\ \text{m}^2 = \pi(d/2)^2$

$d = [4(15.31 \times 10^{-8}\ \text{m}^2)/1\ \pi]^{\frac{1}{2}} = \underline{0.232\ \text{mm}}$

Chapter 19

1. Series: $R = 6(80\ \Omega) = \underline{480\ \Omega}$.

   Parallel: $\frac{1}{R} = 6/80\ \Omega$, $R = \underline{13.3\ \Omega} = \underline{13\ \Omega}$.

2. Maximum in series: $R = 600\ \Omega + 800\ \Omega + 1300\ \Omega = 2700\ \Omega$.
   Minimum in parallel: $1/R = 1/600\ \Omega + 1/800\ \Omega + 1/1300\ \Omega$.
   $R = 271\ \Omega$

3. Put <u>three 1 Ω resistors in series</u>. The voltage across any one resistor is 2 V.

4. (i) All three in series gives $\underline{300\ \Omega}$ as they add (ii) one plus two in parallel. The latter has a resistance of $1/[1/(100\ \Omega) + 1/(100\ \Omega)] = 50\ \Omega$. Thus in total we have $100\ \Omega + 50\ \Omega = \underline{150\ \Omega}$. (iii) Two in series, i.e. 200 Ω, can be connected to 100 Ω in parallel. $R = 1/[(200\ \Omega) + 1/(100\ \Omega)] = \underline{66.7\ \Omega}$. (iv) All three in parallel $R = [3/(100\ \Omega)] = \underline{33.3\ \Omega}$.

5. The upper two resistors are in series, for $2(2.2\ \text{k}\ \Omega) = 4.4\ \text{k}\ \Omega$. This plus the diagonal AB in parallel give $1/[(1/4.4\ \text{k}\ \Omega) + 1/(2.2\ \text{k}\ \Omega)] = 1.47\ \text{k}\ \Omega$. This is in series with BC, for 3.67 k Ω. This is in parallel with AC, for $1/[(1/3.67\ \text{k}\ \Omega + 1/2.2\ \text{k}\ \Omega)] = 1.375\ \text{k}\ \Omega$. This then is in series with the last resistor R, for $1.375\ \text{k}\ \Omega + 2.2\ \text{k}\ \Omega = \underline{3.6\ \text{k}\ \Omega}$.

6. (a) $V = 120\ \text{V}/8 = \underline{15\ \text{V}}$.

   (b) $R = V/I = 15\ \text{V}/(0.6\ \text{A}) = \underline{25\ \Omega}$.
   $P = VI = (15\ \text{V})(0.6\ \text{A}) = \underline{9\ \text{W}}$.

7. Total current through circuit is $8(280 \times 10^{-3}\ \text{A}) = 2.24\ \text{A}$
   Voltage across 2 Ω is $(2.24\ \text{A})(2\ \Omega) = 4.48\ \text{V}$
   Voltage across each light is $(120\ \text{V} - 4.48\ \text{V}) = 115.52\ \text{V}$

   Resistance of each bulb is $\frac{115.52\ \text{V}}{0.280\ \text{A}} = 413\ \Omega$

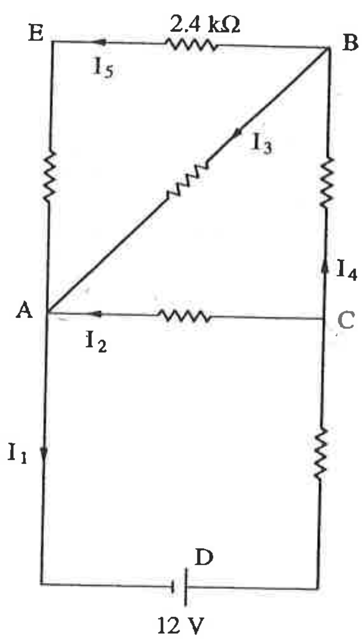
   $$\frac{\text{Power wasted}}{\text{Total Power}} = \frac{I^2R}{IV} = \frac{(2.24\ \text{A})^2(2\ \Omega)}{(2.24\ \text{A})(120\ \text{V})} = 0.0373 \text{ or } \underline{3.73\ \%}$$

8. $(7)(8.0\ \text{W}) = I(120\ \text{V})$. Hence $I = 0.467\ \text{A}$. But for each bulb voltage is $(120\ \text{V})/7$.
   Hence $R = (120\ \text{V})/7/(0.467\ \text{A}) = \underline{36.7\ \Omega}$.

9. In series $P = V^2/R = (120\text{ V})^2/(R_1 + 2.8 \times 10^3\ \Omega)$.
In parallel $4\ P = (120\text{ V})^2[1/R_1 + 1/(2.8 \times 10^3\ \Omega)]$.
Dividing gives $1/4 = (2.8 \times 10^3\ \Omega)(R_1)/(R_1 + 2.8 \times 10^3\ \Omega)^2$.
Solving gives $R = 2800\ \Omega$ or $\underline{2.8\text{ k }\Omega}$.

10. $1/R = 1/R_1 + 1/R_2 = (75\text{ W})/(120\text{ V})^2 + (40\text{ W})/(120\text{ V})^2$. $R = \underline{125\ \Omega}$.

11. Apply Kirchoff's Laws:
Circuit DCA: $12\text{ V} = I_1R + I_2R$
ACB: $-I_2R + I_4R + I_3R = 0$
ABE: $-I_3R + I_5R + I_5R = 0$
Also: $I_1 = I_2 + I_4$, $I_4 = I_3 + I_5$
Solving, $I_5 = 0.385\text{ mA}$
$I_2 = 5I_5 = \underline{1.923\text{ mA}}$
$I_3 = 2I_5 = \underline{0.769\text{ mA}}$
$I_4 = 3I_5 = \underline{1.154\text{ mA}}$
$I_1 = 8I_5 = \underline{3.077\text{ mA}}$
$V_{AB} = I_3R = (0.764\text{ mA})(2.4\text{ k }\Omega) = \underline{1.85\text{ V}}$



12. Total resistance of circuit is $\left[\frac{1}{1.3\text{ k}\Omega} + \frac{1}{1.8\text{ k}\Omega}\right]^{-1} + 1.9\text{ k }\Omega = 2655\ \Omega$.

Thus if ϕ volts is applied to circuit, there is a $\phi\ \frac{1.9\text{ k}\Omega}{2655\ \Omega} = 0.716\ \phi$ voltage across the 1.9 k Ω resistor and a $0.284\ \phi$ across voltage across the other two.

The wattage $P = \frac{V^2}{R}$ and is maximum for the 1.9 k Ω resistor.

This therefore will blow first when $0.716\ \phi = (PR)^{\frac{1}{2}} = [(0.5\text{ W})(1.9\text{ k }\Omega)]^{\frac{1}{2}}$
$\Rightarrow = \underline{43.1\text{ V}}$

13. $V = E - Ir = E\left[1 - \frac{r}{R + r}\right] = (6\ \text{V})\left[1 - \frac{0.6\ \Omega}{7.8\ \Omega}\right] = \underline{5.5\ \text{V}}$

14. $I = \frac{V}{R} = \frac{(4)(1.5\ \text{V})}{(6.2\ \Omega) + 4(0.3\ \Omega)} = \underline{0.811\ \text{A}}$

15. There is effectively zero terminal voltage. Thus $r = E/I = (1.5\ \text{V})/(30\ \text{A}) = \underline{0.05\ \Omega}$.

16. Internal resistance $= \frac{\text{voltage drop}}{\text{current drawn}} = \frac{12\ \text{V} - 8.8\ \text{V}}{70\ \text{A}} = \underline{0.046\ \Omega}$

17. The 8–4 combination in parallel has a resistance of 2.7 Ω. Combined with the 6 and 10 this gives a resistance of 4.8 Ω. The current in circuit is (9 V)/(4.8 Ω + 5.5 Ω) = 0.87 A. Voltage drop across 4.8 Ω is 4.2 V. Voltage across the 2.7 Ω is [(2.7 Ω)/(8.7 Ω)][4.2 V] = 1.3 V. Hence current in 8 Ω resistor is (1.26 V)/(8 Ω) = <u>0.16 A</u>.

18. $I = \frac{V}{R_{net}} = \frac{9}{(8 + 12 + 2)} = 0.41\ \text{A}$

$\Sigma V = 9\ \text{V} - (8\ \Omega)(0.41\ \text{A}) - (12\ \Omega)(0.41\ \text{A}) - (2\ \Omega)(0.41\ \text{A}) = 0$

19. Total emf = 6 V. Total resistance is 9.6 Ω. So $I = (6\ \text{V})/(9.6\ \Omega) = 0.625$ A. The terminal voltage across the 18 V battery is $E - IR = 18\ \text{V} - (0.625\ \text{A})(1\ \Omega) = \underline{17.4\ \text{V}}$.
The terminal voltage across the 12 V battery in which the current is passing the "wrong way" is
$E + Ir = 12\ \text{V} + (0.625\ \text{A})(2\ \Omega) = \underline{13.3\ \text{V}}$.

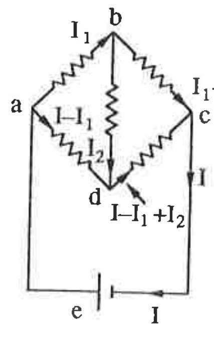
20. Use Kirchoff's rules. Circuit fedhag: $80 = I_2 + 20\ I_2 - 30\ I_1$.
Circuit cbahd: $45 = 41\ I_3 + 30\ I_1$. Also $I_3 = I_1 + I_2$ from point a.
Solving gives $I_1 = -0.858$ A. $I_2 = 2.59$ A, $I_3 = 1.72$ A.
Hence $V_{ad} = -(0.858\ \text{A})(30\ \Omega) = \underline{-25.7\ \text{V}}$.

21. Use I_2 and I_3 from Problem 20.
$V = E - Ir = 45\ \text{V} - (1.72\ \text{A})(1\ \Omega) = \underline{43.3\ \text{V}}$. $V = E - Ir = 80\ \text{V} - (2.59\ \text{A})(1\ \Omega) = \underline{77.4\ \text{V}}$.

22. Upper loop: $9 = 24\ I_2 + 18\ I_1$.
Lower loop: $6 = 24\ I_2$.
Solving, I_1 = <u>0.17 A to left</u>, I_2 = <u>0.25 A to right</u>.

23. Upper loop: $9 = 24\ I_2 + 18\ I_1 + 1\ I_1$.
Lower loop: $6 = 24\ I_2 + 1(I_2 - I_1)$.
Solving, $\underline{I_2 = 0.246\ \text{A}, I_1 = 0.162\ \text{A}}$.

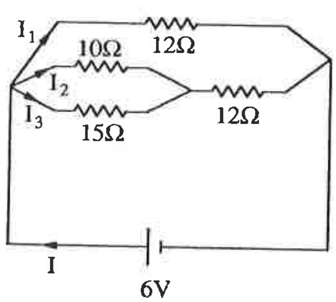
24.



Circuit *eabce*: $6 = 30\ I_1 + 12(I_1 - I_2)$.
Circuit *abd*: $0 = 30\ I_1 + 10\ I_2 - 15(I - I_1)$.
Circuit *bdc*: $0 = 10\ I_2 + 12(I - I_1 + I_2) - 12(I_1 - I_2)$

Solving gives $I = 0.3711$ A, $I_1 = +0.1321$ A, $I_2 = -0.0377$ A
$I_{ab} = I_1 = \underline{0.1321\ \text{A}}$, $I_{ad} = I - I_1 = \underline{0.2390\ \text{A}}$, $I_{bd} = I_2 = \underline{-0.0377\ \text{A}}$
$I_{bc} = I_1 - I_2 = \underline{0.1698\ \text{A}}$, $I_{ac} = I - I_1 + I_2 = \underline{0.2013\ \text{A}}$.

25. The circuit becomes:

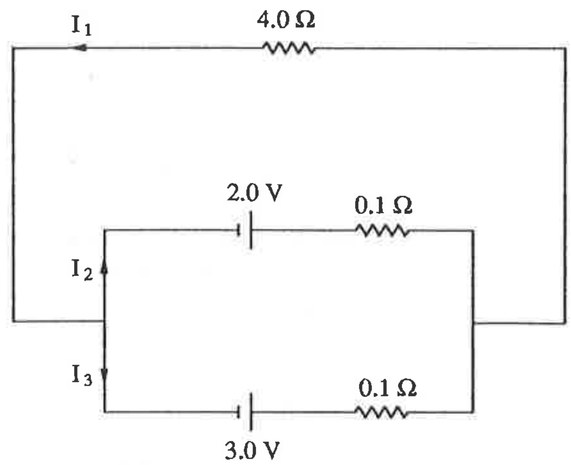


$1/R = 1/12 + 1/[12 + (10)(15)/25]$
$= 1/12 + 1/18$; $R = 7.2\ \Omega$
$I = 6\ \text{V}/7.2\ \Omega = 0.833$ A
$I_1 = 6\ \text{V}/12\ \Omega = \underline{0.5\ \text{A}}$. Thus,
$I_2 + I_3 = \underline{0.333\ \text{A}}$. $I_2 = (0.333)$
$[15/(15 + 10)] = \underline{0.2\ \text{A}}$.
$I_3 = 0.333 - 0.2 = \underline{0.133\ \text{A}}$.

26. Apply Kirchoff's laws to the two independent circuits.
$24 = 11\ I_2 + 21\ I_1$. $18 = 34\ I_3 + 21\ I_1$. And $I_1 = I_3 + I_2$.
Solving gives $I_1 = \underline{0.769\ \text{A}}$, $I_2 = \underline{0.714\ \text{A}}$, $I_3 = \underline{0.0546\ \text{A}}$,
$V = E - Ir = 6\ \text{V} - (0.0546\ \text{A})(1\ \Omega) = \underline{5.96\ \text{V}}$.

27. Apply Kirchoff's laws to the two independent circuits.
$24 = 9\ I_1 + 11\ I_2$. $18 = 34\ I_3 + 9\ I_1$. And $I_2 + I_3 = I_1$.
Solving gives $I_1 = \underline{1.30\ \text{A}}$, $I_2 = 1.12$ A, $I_3 = 0.185$ A.

28. Upper loop: $2 = I_2(0.1) + (I_2 + I_3)4$
Outer loop: $3 = I_3(0.1) + (I_2 + I_3)4$
Adding, $5 = 8.1(I_2 + I_3)$.
$V = (I_2 + I_3)4 = (5/8.1)(4) = \underline{2.47\ \text{V}}$.



29. Parallel: $C_{eq} = 6(2.8\ \mu F) = \underline{16.8\ \mu F}$
Series: $C_{eq} = 1/[6/(2.8\ \mu F)] = \underline{0.467\ \mu F}$

30. $\underline{1.8\ \mu F \text{ in parallel}}$.

31. Want to reduce capacitance, so add capacitor in <u>series</u> with 3600 pF.
$1/(2000\ \text{pF}) = 1/(3600\ \text{pF}) + 1/C$
$C = \underline{4500\ \text{pF}}$

32. $Q_1 = (\varepsilon_0 A_1/d_1)V$. $Q_2 = (\varepsilon_0 A_2/d_2)V$. $Q_3 = (\varepsilon_0 A_3/d_3)V$.
Hence by adding $Q/V = \varepsilon_0(A_1/d_1 + A_2/d_2 + A_3/d_3)$. This is same answer as eq 19–3.

33. (a) $\underline{C = C_1 + 1/(1/C_2 + 1/C_3)}$

(b) $C = 8\ \mu F + 1/[1/(8\ \mu F) + 1/(4\ \mu F)] = 10.67\ \mu F$
Total $Q = CV = (10.67\ \mu F)(60\ V) = 640\ \mu C$
$Q_1 = CV = (8\ \mu F)(60\ V) = \underline{480\ \mu C}$
$Q_2 = Q_3 = (640\ \mu C - 480\ \mu C) = \underline{160\ \mu C}$

34. $C = 1800\text{ pF} + [1/2/(1800\text{ pF})] = 2700\text{ pF}$
$E = CV^2/2 = (2700 \times 10^{-12}\text{ F})(200\text{ V})^2/2 = \underline{5.4 \times 10^{-5}\text{ J}}$

35. For maximum capacitance, put all 3 in parallel.
$C = 3000\text{ pF} + 6000\text{ pF} + 0.010\ \mu\text{F} = \underline{0.019\ \mu\text{F}}$.
For minimum capacitance, put all three in series.
$C = 1/[1/(3000\text{ pF}) + 1/(6000\text{ pF}) + 1/(0.010\ \mu\text{F})] = \underline{1667\text{ pF}}$

36. (a) Total $C = \dfrac{C_1 C_2}{C_1 + C_2} = 0.12\ \mu\text{F}$

Hence Total $Q = CV = (0.12\ \mu\text{F})(9\text{ V}) = 1.08\ \mu\text{C}$
This is charge on each capacitor.

Hence $V_1 = \dfrac{Q}{C} = \dfrac{1.08\ \mu\text{C}}{0.2\ \mu\text{F}} = \underline{5.4\text{ V}}$ and $V_2 = \underline{3.6\text{ V}}$ across $0.3\ \mu\text{F}$ capacitor

(b) $Q = \underline{1.08\ \mu\text{C on each}}$

(c) In parallel, $C = 0.5\ \mu\text{F}$, V across each capacitor is $\underline{9\text{ V}}$.
Hence, $Q_1 = (9\text{ V})(0.2\ \mu\text{F}) = \underline{1.8\ \mu\text{C}}$ and $Q_2 = \underline{2.7\ \mu\text{C}}$.

37. (a) $C = 2\ \mu\text{F} + \dfrac{(5\ \mu\text{F})(4\ \mu\text{F})}{(5\ \mu\text{F}) + (4\ \mu\text{F})} = \underline{4.22\ \mu\text{F}}$.

(b) For the $2\ \mu\text{F}$, voltage is 60 V.
Charge on each capacitor for C_1 and C_2 is $(2.22\ \mu\text{F})(60\text{ V}) = 133.3\ \mu\text{C}$.

$V_1 = \dfrac{133.3\ \mu\text{C}}{5\ \mu\text{F}} = \underline{26.7\text{ V}}$, and $V_2 = \dfrac{133.3\ \mu\text{F}}{4\ \mu\text{F}} = \underline{33.3\text{ V}}$.

38. $R = \tau/C = (3.0\text{ s})/(3 \times 10^{-6}\text{ F}) = \underline{10^6\ \Omega}$.

39. From Problem 17, voltage drop across the 6 Ω is 4.12 V − 1.26 V = 2.86 V.
This is the steady state voltage across the capacitor too, as when fully charged no current flows to it, and it acts as if it had infinite resistance, i.e., were not present at all.
Hence $Q = CV = (3\ \mu\text{F})(2.86\text{ V}) = \underline{8.58\ \mu\text{C}}$.

40. (a) $\tau = RC = (22 \times 10^3\ \Omega)/(0.70 \times 10^{-6}\text{ F}) = \underline{1.54 \times 10^{-2}\text{ s}}$

(b) $10\text{ V} = 12\text{ V}(1 - e^{-t/(1.54 \times 10^{-2}\text{ s})})$
$\exp[-t/(1.54 \times 10^{-2}\text{ C})] = 0.167$
$-t/(1.54 \times 10^{-2}\text{ s}) = -1.79$
$t = \underline{2.76 \times 10^{-2}\text{ s}}$

41. (Change "Now" to "How")
$\tau = RC = (7500\ \Omega)(2 \times 10^{-6}\ F) = 0.015$ s
$0.01\ V = V[e^{-t/(0.015 s)}]$
$\exp[-t/(0.015\ s)] = .01$
$-t/(0.015\ s) = -4.60$ s
$t = \underline{0.0691\ s}$

42. (a) $V_a = (24\ V)(4.4\ \Omega)/(8.8\ \Omega + 4.4\ \Omega) = \underline{8\ V}$.

(b) Total capacitance is $C_1C_2/(C_1 + C_2) = 0.16\ \mu F$.
Hence Q on each capacitor is $(24\ V)(0.16\ \mu F) = 3.84\ \mu C$.
Hence V_b is $(3.84\ \mu C)/(0.24\ \mu F) = \underline{16\ V}$.

(c) When S is closed $V_a - V_b$ is eventually zero. So $V_b = V_a = \underline{8\ V}$.

(d) Charge in region b is $-3.84\ \mu C + 3.84\ \mu C$ = zero when S is open.
When S is closed charge on $0.24\ \mu F$ capacitor is $(0.24\ \mu F)(8\ V) = 1.92\ \mu C$.
Charge on $0.48\ \mu F$ is $(0.48\ \mu F)(16\ V) = 7.68\ \mu C$.
Thus total flow of charge from b to a is $-7.68\ \mu C + 1.92\ \mu C = \underline{-5.76\ \mu C}$.

43. $R = (30000\ \Omega/V)(5.0\ V) = 150$ kV

$I = (1.0\ V)/(5000\ \Omega) = \underline{200\ \mu A}$.

45. Short it with a resistance that passes (10 A – 120 mA) = 9.88 A when 10 mV is placed across it, i.e., $R = V/I = (10\ mV)/(9.88\ A) = \underline{1.012 \times 10^{-3}\ \Omega}$.

46. The voltage for full scale deflection is $IR = (70 \times 10^{-6}\ A)(30\ \Omega) = 2.1 \times 10^{-3}$ V.

(a) For an ammeter, need a shunt resistance in parallel that passes (15 A – 70 μA) when subject to a 2.1×10^{-3} V potential.
$R = V/I = \underline{1.4 \times 10^{-4}\ \Omega}$.

(b) We need a multiplier resistance in series that has a potential of (3000 V – 2.1×10^{-3} V) when a current of 70×10^{-6} A passes through it.
$R = V/I = \underline{4.29 \times 10^{7}\ \Omega}$.

47. (a) Full scale sensitivity = $1V/(50000\ \Omega) = 0.02$ mA.
Voltage across galvanometer at full reflection is $(28\ \Omega)(0.02\ \text{mA}) = 5.6 \times 10^{-4}$ V. We nee shunt resistance that will carry $(10\ \text{mA} - 0.02\ \text{mA}) = 9.98$ mA at 5.6×10^{-4} V, or
$R = V/I =$ <u>0.0561 Ω</u>.

(b) We need a "multiplier" resistance in series such that when a current of 0.02 mA passes through i we have a voltage drop of 100 mV − 0.56 mV = 99.44 mV, so
$R = V/I = (99.44\ \text{mV})/(0.2\ \text{mA}) =$ <u>4972 Ω</u>.

48. At full scale the current running through the milliammeter is 10 mA.
The resistance is $R_1R_2/(R_1 + R_2) = (30\ \Omega)(0.2\ \Omega)/(30.2\ \Omega) = 0.199\ \Omega$.
Thus full voltage for full deflection is $IR = 0.00199$ V. We must therefore add a multiplier <u>resistance in series</u> with the milliammeter such that when a (10 V − 0.00199 V) potential is applied 10 mA runs through it. Hence $R = V/I =$ <u>1000 Ω</u>. Sensitivity is 1000 Ω/10 V = <u>100 Ω/V</u> which is not very good.

49. Before connecting the voltmeter voltage across the 37 k Ω and 42 k Ω resistances are $90\ \text{V}\left[\frac{37\ \text{k}\,\Omega}{79\ \text{k}\,\Omega}\right]$ and $90\ \text{V}\left[\frac{42\ \text{k}\,\Omega}{79\ \text{k}\,\Omega}\right]$, i.e. 42.15 V ana 47.85 V respectively. The voltmeter is assumed not to affect this voltage but in fact it does and the voltmeter measures the changed voltage. For the 42 k Ω measurement, the resistance now is $42\ \text{k}\,\Omega\left[\frac{100\ \text{k}\,\Omega}{142\ \text{k}\,\Omega}\right] = 29.58\ \text{k}\,\Omega$.

Thus the voltmeter reads $\dfrac{(90\ \text{V})(29.58\ \text{k}\,\Omega)}{(29.58\ \text{k}\,\Omega + 37\ \text{k}\,\Omega)} = 40$ V.

For the 37 k Ω measurement, the resistance is $37\ \text{k}\,\Omega\left[\frac{100\ \text{k}\,\Omega}{137\ \text{k}\,\Omega}\right] = 27.0\ \text{k}\,\Omega$.

The voltmeter reads $\dfrac{(90\ \text{V})(27\ \text{k}\,\Omega)}{(27\ \text{k}\,\Omega + 42\ \text{k}\,\Omega)} =$ <u>35.2 V</u>.

The error in the first reading is $\dfrac{47.85\ \text{V} - 40\ \text{V}}{47.85\ \text{V}} =$ <u>16.4%</u> low

The error in the second reading is $\dfrac{42.15\ \text{V} - 35.2\ \text{V}}{42.15\ \text{V}} =$ <u>16.4%</u> low

50. $E = \Sigma Ir = (3.2 \times 10^{-3}\ \text{A})(80\ \Omega + 800\ \Omega + 500\ \Omega) = 4.416$ V
When the ammeter is removed,

$I = \dfrac{4.416\ \text{V}}{1300\ \Omega} =$ <u>3.40 mA</u>

51. The resistance of the voltmeter and the 6 k Ω is $\frac{R_1 R_2}{R_1 + R_2} = 4.286$ k Ω.

Total resistance of circuit is 10.2875 k Ω.

So, current is $\frac{9 \text{ V}}{10.2875 \times 10^3 \, \Omega} = \underline{0.875 \text{ mA}}$.

This is what the ammeter reads.
The voltage drop comes across the voltmeter is (4.286 k Ω)(0.875 mA) = $\underline{3.75 \text{ V}}$.

52. Internal resistance of voltmeter is (1000 Ω/V)(3 V) = 3000 Ω.
Effective resistance of 8.9 k Ω resistors when shunted by voltmeter

is $\frac{R_1 R_2}{R_1 + R_2} = \frac{(8.9 \text{ k}\,\Omega)(3 \text{ k}\,\Omega)}{11.9 \text{ k}\,\Omega} = 2.24$ k Ω.

But voltmeter reads 2 V; hence current through system is $\frac{V}{R} = 0.89$ mA.

E = (0.89 mA)(8.9 k Ω + 2.24 k Ω) = $\underline{9.93 \text{ V}}$.

53. Voltage across the 15 k Ω resistance without the voltmeter is 4 V.
Assume 4 V(0.97) = 3.88 V is voltage when voltmeter is attached.
Current through remaining 15 k Ω resistance is (8 V − 3.88 V)/(15 K Ω) = 0.274667 mA.
Current through first 15 k Ω resistance is (3.88 V)/(15 k Ω) = 0.258667 mA.
Current through voltmeter is the difference, i.e. 0.0160 mA.
Thus $R = V/I$ = (3.88 V)/(0.0160 mA) = $\underline{243 \text{ k}\,\Omega}$.

54. The resistance of the voltmeter in the first case is (20,000 Ω/V)(100 V) = 2000 kΩ. The effective resistance of the 120 kΩ and 2000 kΩ in parallel is (2000 kΩ)(120 kΩ)/(2120 Ω) = 113.2 kΩ.
Thus $I = (V/R)$ = (25 V)/(113.2 kΩ) = 0.2208 mA. Thus E = 0.2208 mA(113.2 kΩ + R_2).
In the next case the resistance of the voltmeter is (20,000 Ω/V)(30 V) = 600 kΩ.
The effective combination resistance is R = (600 kΩ)(120 kΩ)/(720 kΩ) = 100 kΩ.
Thus I = (23 V)/(100 kΩ) = 0.23 mA. E = 0.230 mA(100 kΩ + R_2).
E = (0.2208 mA)(113.2 kΩ + R_2). Solving, $0.0091667R_2 = 1.998$.
Hence R_2 = $\underline{218 \text{ k}\Omega}$. E = 73.1 V. V = (73.1 V)(120 kΩ)/(120 kΩ + 218 kΩ) = 26.0 V.

55. Let I be current through battery in the first case and I_g be current through voltmeter.

$I_g = \frac{3 \text{ V}}{10 \text{ k}\Omega} = 0.3$ mA. $I - I_g = \frac{3}{R_1}$ and $IR_2 = 9 \text{ V} - 3 \text{ V} = 6$ V.

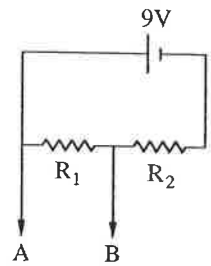
Hence $\frac{6}{R_2} - 0.3 \times 10^{-3} = \frac{3}{R_1}$.

In second case, $I_g = \frac{4 \text{ V}}{10 \text{ k}\Omega} = 0.4$ mA. $I - I_g = \frac{4}{R_2}$ and $IR_1 = 9 \text{ V} - 4 \text{ V} = 5$ V.

Hence $\frac{5}{R_1} - 0.4 \times 10^{-3} = \frac{4}{R_2}$.

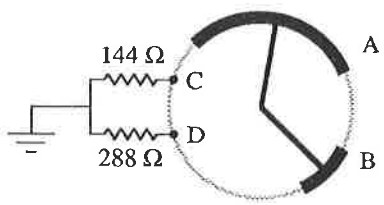
Solving, R_1 = $\underline{5 \text{ k}\Omega}$ and R_2 = $\underline{6.7 \text{ k}\Omega}$.

56.



Let $IR_1/I(R_1 + R_2) = (0.25\text{ V})/(9\text{ V})$.
Then $R_1 = 0.0286\ R_2$. At the moment the voltage across AB 0.25 V and the resistance is infinite. If we make R_2 small abou. 1 Ω and connect AB to a 2000 Ω resistance nothing will change as 2000 Ω ≫ 0.0286 Ω. So an arrangement is $R_2 = 1\ \Omega$, $R_1 = 0.0286\ \Omega$.

57.



$P = V^2/R$. 50 $W \rightarrow R = (120\text{ V})^2/50 = 288\ \Omega$. The 100 W and 150 W give 144 Ω and 96 Ω respectively.
If 288 Ω and 144 Ω are connected in parallel
$R = (288\ \Omega)(144\ \Omega)/(288 + 144\ \Omega) = 96\ \Omega$. Possible connection is shown in diagram. If A touches CD 96 Ω. If B touches C only or D only 144 Ω or 288 Ω is the resistance.

58. $V = IR = (3.0\text{ A})(300\text{ m})(0.0065\ \Omega/\text{m}) = \underline{5.8\text{ V}}$,
i.e, applied voltage is 120 V − 5.8 V = $\underline{114\text{ V}}$ = 1.1×10^2 V.

59. $I = V/R = (220\text{ V})/(3 \times 10^4\ \Omega) = \underline{7.33 \times 10^{-3}\text{ A}}$.

60. (a) Total $C = 0.6\ \mu\text{F}$. Energy $= \dfrac{CV^2}{2} = \underline{4.32 \times 10^{-5}\text{ J}}$.

Note this neglects ohmic loss in battery.

(b) In series, $C = \dfrac{C_1 C_2}{C_1 + C_2} = 0.133\ \mu\text{F}$. Energy $= \dfrac{CV^2}{2} = \underline{9.6 \times 10^{-6}\text{ J}}$.

(c) Charge in case (a), $Q = CV = (0.6 \times 10^{-6}\text{ F})(12\text{ V}) = \underline{7.2 \times 10^{-6}\text{ C}}$.
In (b), $Q = CV = (0.133\ \mu\text{F})(12\text{ V}) = \underline{1.6 \times 10^{-6}\text{ C}}$.

61. $V = E(1 - e^{-t/RC})$. If $t = RC$, $V = 0.63$ E.
Thus, we need $R = t/C = (60\text{ s}/70)/(4 \times 10^{-6}\text{ F}) = \underline{2.14 \times 10^{-5}\ \Omega}$.

62. (a) Response drops to 0.37 times that at t = 2 ms in about 0.3 ms., thus τ = 0.3 ms.

(b) $R = \tau/C = (0.3 \times 10^{-3})/(10^{-8}\text{ F}) = \underline{3 \times 10^4\ \Omega}$.

63. Let r be the internal resistance of the cells and R the resistance of the hearing aid. None of the cells will deliver full voltage. The "terminal" voltage for the mercury cells is 3(1.35 V)(1 – $3r/(3r + R)$). Here $R = V^2/P = 8\ \Omega$. So delivered terminal voltage is 4.00 V.
Similarly the dry cells deliver 3(1.5 V)[1 – $3r/(3r + R)$] = 3.98 V. The power wasted in the mercury cell is $V^2/3r$ = (4.05 V – 4.00 V)^2/3/(0.03 Ω) = 0.0278 W. The power wasted in the dry cell is (4.5 V – 3.98 V)^2/3/(0.3 Ω) = 0.30 W, i.e. dry cells run down faster.

64. (a) $I = \dfrac{V}{R} = \dfrac{120\text{ V}}{1000\ \Omega} = \underline{0.12\text{ A}}$.

(b) It makes no difference to the voltage applied to the body, thus $I = \underline{0.12\text{ A}}$.

(c) The voltage is no longer 120 V.

The two resistances have a total resistance of $\dfrac{(1000\ \Omega)(30\ \Omega)}{1030\ \Omega} = 29.1\ \Omega$.

There is internal resistance of source

$r = \dfrac{120\text{ V}}{1.4\text{ A}} = 85.7\ \Omega$.

Total resistance = 114.8 Ω.

The current is $\dfrac{120\text{ V}}{114.8\ \Omega} = 1.045\text{ A}$.

The voltage across the body is IR = 30.4 V.

The current through the body is $\dfrac{30.4\text{ V}}{1000\ \Omega} = \underline{30.4\text{ mA}}$.

65. (a) $I_3R_3 = I_1R_1$ and $I_3R_x = I_1R_2$

So $\dfrac{I_3R_x}{I_3R_3} = \dfrac{I_1R_2}{I_1R_1}$

So $R_x = \dfrac{R_2}{R_1}R_3$

(b) $R_x = R_3\left[\dfrac{R_2}{R_1}\right] = (2.34\text{ k}\Omega)\left[\dfrac{848\ \Omega}{410\ \Omega}\right] = \underline{4.84\text{ k}\Omega}$.

66. $R_x = R_3\left[\dfrac{R_2}{R_1}\right] = (4.76\ \Omega)\left[\dfrac{84\text{ cm}}{36\text{ cm}}\right] = 11.1\ \Omega = \dfrac{\rho \ell}{A}$

$11.1\ \Omega = \dfrac{\ell(10.6\times 10^{-8}\ \Omega\cdot\text{m})}{\pi(0.6\times 10^{-3}\text{ m})^2}$. Hence $\ell = \underline{118\text{ m}}$.

67. (a) $V_{AC} = E_x$

$E_x = IR_x$ and $E_S = IR_S$

So $\dfrac{E_x}{E_S} = \dfrac{IR_x}{IR_S}$

$E_x = \left[\dfrac{R_x}{R_S}\right] E_S$

(b) $E_2 = E_1\left[\dfrac{\ell_2}{\ell_1}\right] = (1.0182\ \text{V})\left[\dfrac{13.8\ \text{cm}}{31.7\ \text{cm}}\right] = \underline{0.443\ \text{V}}$

(c) The voltage may not be exactly balanced $\Delta V = (40\ \Omega)(0.015\ \text{mA}) = \underline{6 \times 10^{-4}\ \text{V}}$. This of cours could be of either sign.

(d) When subtracting two large numbers whose difference is close to zero, better precision can b obtained by measuring the difference directly than by measuring the numbers individually. Th "null" method measures this difference between large numbers.

68. (a) All the negative plates have the same potential as do all the positive plates. They are in parallel.

(b) $C = (7)(1 \times 10^{-4}\ \text{m}^2)(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)/(0.001\ \text{m}) = \underline{6.195\ \text{pF}}$ is minimum value. Maximum value is $(4 \times 10^{-4}/\text{m}^2)(6.195\ \text{pF})/(1 \times 10^{-4}\ \text{m}^2) = \underline{24.8\ \text{pF}}$.

69. $V = E - Ir$, $50 = E - 6.5r$, and $58.2 = E - 2.8r$.
Solving, $r = \underline{2.22\ \Omega}$, $E = \underline{64.4\ \text{V}}$.

70. Connect N resistors, each at value r, in parallel. Total resistance is $1.8\ \text{k}\Omega = r/\text{N}$.

$V = (PR)^{\frac{1}{2}} = [(5\ \text{W})(1.8\ \text{k}\Omega)]^{\frac{1}{2}} = [(0.5\ \text{W})r]^{\frac{1}{2}}$

$(0.5)r = 9000\ \Omega$

$r = 18000\ \Omega = \underline{18\ \text{k}\Omega}$.

$\text{N} = 18000\ \Omega/1.8\ \text{k}\Omega = \underline{10}$.

71. There are two answers because the current can flow two ways in $4\ \Omega$ resistor.

$V_{4k\Omega} = (350\ \text{mA})(4\ \text{k}\Omega) = 1400\ \text{V}$.

Current in $8\ \text{k}\Omega$ resistor $= \dfrac{1400\ \text{V}}{8\ \text{k}\Omega} = 175\ \text{mA}$.

Total current = 525 mA.

Assume current is left to right in $4\ \text{k}\Omega$.

$V_{ab} - (525 \times 10^{-3})(5 \times 10^{3}) - 1400 - 12 - (525 \times 10^{-3})(1) = 0$

$V_{ab} = \underline{4037.5\ \text{V}}$.

If current flow is from right to left in $4\ \text{k}\Omega$,

$V_{ab} + (525 \times 10^{-3})(5 \times 10^{3}) + 1400 - 12 + (525 \times 10^{-3})(1) = 0$

$V_{ab} = \underline{-4013.5\ \text{V}}$.

72. For half scale deflection the voltage drop across the galvonometer is $(30\ \Omega)(15 \times 10^{-6}\ \text{A}) = 4.5 \times 10^{-4}\ \text{V}$.
Assuming the current through the shunt is I, then $R_{sh}I = 4.5 \times 10^{-4}\ \text{V}$
and also $(9\ \text{V} - 4.5 \times 10^{-4}\ \text{V}) = (I + 15 \times 10^{-6}\ \text{A})(30 \times 10^{3}\ \Omega + R_{ser})$
$= (4.5 \times 10^{-4}/R_{sh} + 15 \times 10^{-6})(30{,}000 + R_{ser})$.
If the 30 kΩ resistance is removed the ammeter has full deflection. The voltage drop across the galvonometer is $(30\ \Omega)(30 \times 10^{-6}\ \text{A}) = 9 \times 10^{-4}\ \text{V}$.
As above, we deduce $(9\ \text{V} - 9 \times 10^{-4}\ \text{V}) = (9 \times 10^{-4}/R_{sh} + 30 \times 10^{-6})(R_{ser})$.
We solve these two equations to obtain $R_{sh} = \underline{3.33\ \Omega}$ and $R_{ser} = \underline{30\ \text{k}\Omega}$.

Chapter 20

1. (a) $F/\ell = IB \sin\theta = (3.6 \text{ A})(1.20\ T)\sin(90°) = \underline{4.32 \text{ N/m}}$.

   (b) $F/\ell = (3.6 \text{ A})(1.20 \text{ J})\sin(45°) = \underline{3.05 \text{ N/m}}$.

2. $B = F/I\ell = (3.80 \text{ N})/(30 \text{ A})(0.25 \text{ m})] = \underline{0.507 \text{ T}}$.

3. $I = F/\ell B = (0.9 \text{ N})/[(3.0 \text{ m})(0.080 \text{ T})] = \underline{3.75 \text{ A}}$.

4. $F = I\ell B \sin\theta = (280 \text{ A})/(180 \text{ m})(5 \times 10^{-5} \text{ T})\sin(60°) = 2.18 \text{ N}$.

5. $F = qvB = (1.6 \times 10^{-19} \text{ C})(2.84 \times 10^{5} \text{ m/s})(1.60 \text{ T}) = \underline{7.27 \times 10^{-14} \text{ N}}$.
   Force is <u>North</u>. Remember electron has negative charge.

6. $F = qvB = mv^2/r$. The proton will move in a circle in a clockwise direction in a plane perpendicular to the magnetic field.
   $r = mv/qB = (1.67 \times 10^{-27} \text{ kg})(8.25 \times 10^{6} \text{ m/s})/[(1.6 \times 10^{-19} \text{ C})(0.180 \text{ T})] = \underline{0.478 \text{ m}}$.

7. (a) <u>Out</u>

   (b) <u>Right</u>

   (c) <u>Up</u>

   (d) <u>Right</u>

   (e) <u>Down</u>

   (f) <u>Zero</u>

8. (a) <u>In</u>

   (b) <u>Right</u>

   (c) <u>Down</u>